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Research paper

Operationalizing a land systems classification for Laos

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ABSTRACT

Land cover data is widely used for the design and monitoring of land use policies despite the incapability of this type of data to represent multiple land uses and land management activities within the same landscape. In this study, we operationalized the concept of land systems for the case of the Lao PDR (Laos). Distinct land systems like shifting cultivation and plantations (land concessions) cannot be fully captured by land cover inventories alone, in spite of their relevance for land use policies. Using a decision tree and a matrix approach, we integrated several datasets for the period 2010/11, including land cover, an agricultural census and a land concession inventory. We selected thresholds for distinguishing land systems based on an expert survey. The resulting 17 land systems cover the whole territory of Laos and represent landscapes of 2 × 2 km pixel size. The largest area is occupied by smallholder agriculture land systems intertwined with forests. Only 27% of the territory are agriculturally undisturbed, dense forest systems. The assessment can serve as a basis to identify areas that could change shortly and locates the full range of land systems, from land concessions to smallholder systems, in one, integrated spatial assessment. The land system representation can help policy makers to link land systems to the diversity of different stakeholders and their backgrounds and support discussions about ecologic and socio-economic consequences of different land uses within a landscape.

1. Introduction

Land change and particularly the social dimensions of land change have repeatedly been identified as key leverage point to mitigate and adapt to global environmental change by designing sustainable and resilient landscapes (Davidson, 2016; Tscharntke et al., 2012; Turner, Janetos, Verburg, & Murray, 2013). Assessments of land change are important to identify unsustainable or vulnerable landscapes and monitor efficiency of adaptation and mitigation measures. The most common means of observation is remote sensing, therefore land cover is the most widely used type of data for land change assessments (Verburg, Neumann, & Nol, 2011; Verburg, Van de Steeg, Veldkamp, & Willemen, 2009). While remote sensing techniques are able to capture biophysical information at increasingly finer spatial resolutions and shorter time intervals, they insufficiently represent socio-economic aspects and differences in land use (Van Asselen & Verburg, 2012). A one-to-one translation is problematic since one type of land cover is in fact related to many functions and uses (Verburg et al., 2009). For instance, land covered with forest can be used for periodic timber extraction, wild food collection and recreation at the same time, while this cannot be inferred from satellite imagery. Furthermore, the same type of land cover (e.g. oil palm plantations) can be managed by different types of stakeholders (e.g. smallholders or large agribusinesses) who each are linked to different types of networks (kinship ties versus multinational corporate networks respectively). Again, this cannot be identified by remote sensing, or from already aggregated categories in land cover classifications. Thereby thematic and semantic inconsistencies propagate through to policy design if they are not taken into account in the interpretation of land change assessments (Comber, 2008; Comber, Wadsworth, & Fisher, 2008). Accompanying information is required to allow for a more systemic representation of the multiple functions and actors related to land (Kruska, Reid, Thornton, Henninger, & Kristjanson, 2003; Verburg et al., 2009).

The land science community shifted its focus on analyzing *land systems*, a concept closely related with and often interchangeably referred to as coupled human-natural systems, human environmental systems (GLP, 2005) or socio-ecological systems (SES) (Binder, Hinkel, Bots, & Pahl-Wostl, 2013; Lambin & Meyfroidt, 2010; McGinnis & Ostrom, 2014; Sakai & Umetsu, 2014). Broadly defined, land systems *'represent the*

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terrestrial component of the Earth system and encompass all processes and activities related to the human use of land, including socioeconomic, technological and organizational investments and arrangements, as well as the benefits gained from land and the unintended social and ecological outcomes of societal activities' (Verburg et al., 2013, p. 433). In short, land systems capture the ecological and socio-economic characteristics of land but spatially explicit data describing land systems are not collected as a single dataset to date. Instead, to prepare a land systems classification, several, independently collected datasets need to be integrated. In order to characterize land systems with their socio-ecologic characteristics and multifunctionality, data that is collected for different purposes must be merged. Applications of concepts that better illustrate human-environment interdependencies have focused on the continental to global scale and include, among others, the Anthromes framework (Ellis & Ramankutty, 2008), a global mosaic land systems representation (Van Asselen & Verburg, 2012) and Land System Archetypes (Václavík, Lautenbach, Kuemmerle, & Seppelt, 2013).

Assessing land systems becomes especially critical at scales above the sub-national level (Boillat et al., 2015; Messerli, Bader, Hett, Epprecht, & Heinimann, 2015; Schmidt-Vogt et al., 2009). At these larger spatial scales, land cover data often becomes aggregated to larger units, while losing the mosaic of different, functionally important land use and land cover types (Verburg et al., 2011). Farming systems shape the diversity of land cover and land systems to a large degree (Van der Ploeg & Ventura, 2014). However, the coarseness of global assessments often neglects the farming system diversity relevant within a country and may not address the types significant to national policy making. Typologies of farming systems have been created in the past (see Kruska et al., 2003 for an overview; and Van de Steeg et al., 2010 for an application in Kenya) but as they focus on agricultural systems alone they often do not show the links of agriculture with forest systems or other land uses. For sustainable landscapes that are adapted to the politically relevant, socio-economic setting of an area, assessments are needed that include the types of land use relevant at the spatial scale of land change policies and land management (Moran, 2010). In other words, the land systems concept needs to be operationalized at a politically relevant scale to be effective in serving the creation and revision of land use policies beyond the information that land cover datasets and analyses can convey. Choosing an appropriate scale of analysis is not trivial because there may be a difference between the scales at which end users require spatially explicit information and the scales at which the processes take place (Van Delden, Van Vliet, Rutledge, & Kirkby, 2011). We argue, that for the land systems concept to be adopted in practice, the needs of end users (i.e. policy makers) should be the point of departure. Covering the spatial extent of their interest and the types of land uses occuring in this area is essential. What scale can be identified as politically relevant further depends on the governance structure of the respective place. For many locations, country scale assessments represent the highest level of autonomy and control regarding land use policies. This is also the case for the Lao People's Democratic Republic (Laos) where the socialist government form implies centralized planning and policies, even if bottom-up, participatory planning has been part of local land governance too (Sandewall, Ohlsson, & Sawathvong, 2001).

In Laos, like in other tropical regions, there are specifically two land system types that are important for current land use policies but cannot be monitored fully with land cover information alone: shifting cultivation (Schmidt-Vogt et al., 2009), and land concessions (Schönweger et al., 2012). Land concessions are frequently large in area, granted to foreign investors and therefore referred to as large scale land acquisitions (LSLA). In shifting cultivation, active agricultural use of a plot alternates with periods of forest regrowth for sometimes more than ten years (Ducourtieux, Laffort, & Sacklokham, 2005). As it is a very dynamic land use which requires wide areas and several years for a full cropping cycle, time series of comparable land cover data are normally needed to map its spatial extent (Hurni, Hett, Heinimann, Messerli, & Wiesmann, 2012). Hurni et al. (2013) developed a texture-based technique using land metrics to identify the extent of shifting cultivation based on a single remote sensing dataset alone. However, this method is of limited accuracy in mountainous terrain, broad land cover categories and areas of heterogenous land uses (Hurni et al., 2013). Land cover classifications often lack a clear category on shifting cultivation, because it is challenging to identify it completely with remote sensing. Instead, shifting cultivation is scattered over several classes, which are named in a way that masks the (temporary) agricultural use of the respective area such as 'unstocked forests', 'secondary forests', 'shrub', or 'open forest'. These are some of the reasons, why quantification of the extent and location of shifting cultivation landscapes is difficult with land cover data (Heinimann et al., 2013; Heinimann, Messerli, Schmidt-Vogt, & Wiesmann, 2007; Mertz, Leisz et al., 2009; Padoch et al., 2007; Schmidt-Vogt et al., 2009). Likewise, land concessions are not easily and clearly captured in land cover assessments and it is challenging to distinguish their characteristics from smallholder farming with similar crops or from forests. In Vietnam for example, recent reforestation occurred due to commercial tree plantations (Meyfroidt, Vu, & Hoang, 2013). While both natural reforestation and commercial tree plantations lead to a forest land cover they imply different management and biodiversity characteristics. Furthermore, land for which concessions were obtained does not necessarily exhibit immediate land cover change since some investors keep the land for speculation (Anseeuw et al., 2012). Yet, this land is unavailable to smallholders or other users.

For Laos, an assessment that includes both shifting cultivation and land concessions (LSLA) with information complementary to land cover is needed, since these land uses are part of two ongoing processes with long lasting effects: (i) the agrarian transition from subsistence to market oriented economy by an increase of cash cropping (Baird, 2009; Castella, Lestrelin, & Buchheit, 2012; Thongmanivong, Yayoi, Phanvilay, & Vongvisouk, 2009) and (ii) telecoupled land acquisitions (Friis, Nielsen, Otero, Haberl, & Hostert, 2015; Friis & Østergaard Nielsen, 2016; Liu et al., 2013).

The objective of this study is to operationalize the concept of land systems by developing a national scale representation of land systems for the case of Laos that captures different types of agricultural and forest systems. To achieve this, we integrated land cover data with an agricultural census and maps of land concessions from which we created a typology with 17 land systems. In this article, we present our data integration approach, describe the mapping result in relation to other land change assessment products and discuss the result as a basis for widening policy debates towards a systemic 'land system' view on land in Laos.

2. Material and methods

2.1. Data

The major land uses and land covers, that shape the largest part of Laos include forest cover, large scale land acquisitions (LSLA, hereafter called land concessions) and different forms of smallholder cropping systems (shifting cultivation, permanent cultivation and a mixed form of them labeled as transition from subsistence to cash cropping). Urban areas are taken into account as well, however, in Laos their size and influence relative to agricultural and forested areas is marginal, hence we did not focus on their role in this study. In order to create a typology of the major land systems we combined essentially three main datasets (land cover inventories, agricultural census, and land concessions inventory) and two auxiliary datasets (water bodies and accessibility in terms of travel time to next village) as listed in Table 1.

Together, the datasets reflect the land system situation for the period 2010–2012. The original datasets differed in their basic geometry and spatial units of reference. While forest cover, land concessions and water bodies (partly) had original geometries displaying physical units or plot level tenure information, the agricultural census